Wireless Mobile Telemedicine: En-Route Transmission With Dynamic Quality-of-Service Management

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OVERVIEW

For time-sensitive, critical-care scenarios requiring transport—such as stroke, high-risk pregnancy, trauma, and pediatric care—reducing the elapsed time between symptom onset and treatment can be of great benefit to the patient while reducing the health care costs to the individual, the hospital, and the public. With mobile telemedicine, *valuable prehospital transport time can be used to diagnose and evaluate the patient en route*[1,2]. Heretofore, the usefulness of prehospital time has been limited to ensuring minimum life-support activities. The use of wireless communications linking prehospital providers with emergency care specialists can transform the prehospital phase of *transport* into a prehospital phase of *treatment.*

During the past 5 years, TRW Inc. and the University of Maryland School of Medicine have prototyped a system for transmitting real-time patient vital signs data and audio and video images of care activities from inside an ambulance en route to a trauma center using wireless communications and in-hospital Intranet technology (Figure 1). Our team designed, integrated, and installed in three ambulances a Mobile Telemedicine System (MTS)[3] using commercial, off-the-shelf equipment, with data management and physician interface software developed in JAVA.
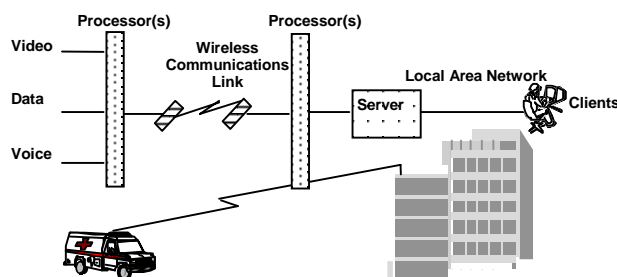

Figure 1. Mobile Transmission of Emergency Data

Our ultimate goal is to improve the quality and timeliness of care provided during the "golden window" of treatment opportunity immediately following injury and provide better information to the hospital staff prior to patient arrival.

CLINICAL EVALUATION MODEL

Our team has focused on speeding the treatment of brain attack (acute ischemic stroke) patients as our primary clinical model (Figure 2). Stroke is the number-one cause of adult disability in America and the number-three killer. Brain attack is a time-critical emergency during which brain tissue is being deprived of oxygen. Treatment options exist, yet these options are constrained by the delay between symptom onset and definitive diagnosis. Tragically, the overwhelming majority of patients (>97 percent) miss the brief 3-hour window of opportunity for treatment[4,5]. Using the MTS to transmit diagnostic information en route shortens delays to therapeutic treatment, thereby increasing

Brain Attack: Time Is Brain	
Background:	Maximum 3-hour "window" from symptom onset for administration of tissue plasminogen activator
Protocol:	Neurologist at hospital views patient vital signs and the administration of the National Institutes of Health Stroke Scale in ambulance by emergency medical technician
Measure:	Time from arrival at hospital to definitive diagnosis of stroke—compare with time to diagnosis prior to use of Mobile Telemedicine System

the available treatment options and improving patient outcomes.

Figure 2. Brain Attack as Primary Clinical Model

PRINCIPLE PROVEN?

The prototype MTS has been used successfully on more than a dozen trauma patient transfers. Feedback received from these patient runs suggests that the system can provide significant useful clinical information (Figure 3).

Figure 3. Summary of Key Project Results

When the system is up and running, hospital staff members are ecstatic and have responded with such enthusiastic expressions as "This is amazing, absolutely fantastic." Unfortunately, the prototype system as developed has stability issues that currently limit its use.

Chief among these are the stability and reliability of the wireless transmission link, with the majority of patient transfers unable to complete the entire NIH Stroke Scale. Nevertheless, even a partial patient assessment can provide significant clinical information, for example, during transport to alter a patient's treatment plan by ruling out tissue plasminogen activator therapy. Although this work demonstrated the potential for using mobile telemedicine, a more stable system is required for the widespread adoption of the technology.

OVERCOMING QUALITY-OF-SERVICE LIMITATIONS

The combination of instability in the commercial system components underlying our MTS and unpredictable wireless communications connectivity and bandwidth result in system performance that is inconsistent from run to run. The variability of the system performance frustrates the receiving physician's conduct of the remote patient examination and undermines the physician's trust in the system's ability to perform in a critical-care environment.

Fundamentally, the key barrier to the adoption of the MTS has been an inability to reliably attain the requisite Quality of Service (QOS) for the clinical model in question (i.e., the demanding "brain attack" clinical model). Meeting the QOS challenge has caused us to reexamine our system's design.

Our team returned to the system design and has spent the past 2 years redesigning and reimplementing our system to address the QOS shortfalls of our prototype MTS. As a result, the following system enhancements are under way:

- Less reliance on commercial systems integration. Our revised system relies on fewer commercial components, allowing our team to rapidly identify and correct problems.
- Creation of a hybrid connectivity architecture using overlapping wireless infrastructures. By taking advantage of the overlapping network coverage provided by competing network providers, higher aggregate data throughput and improved cell-to-cell connectivity can be achieved. Furthermore, our system combines different types of wireless connectivity, including both "always-on" Internet-Protocol-based connectivity and more traditional dial-up cellular communications. The resulting QOS-smart communications architecture allows dynamically optimizing the underlying communications channels for bandwidth, delay, throughput, stability, and cost.
- Bidirectional QOS control. Our revised system now allows the receiving physician to dynamically reprioritize the data transmission to optimize bandwidth utilization and data throughput. For example, the receiving physician can alter the frequency and quality of the images transmitted or may opt to turn on or off the waveform and numerical vital signs information being sent by the patient monitor. Providing this level of control alongside a dynamic graphical QOS display provides the physician with the ability to direct QOS delivered by the system in real time.
- Adoption of a wavelet image compression algorithm. Moving from the current JPEG format to a wavelet/fractal image compression scheme produces a twofold to fivefold improvement factor in the image data throughput without noticeably degrading the quality of the transmitted images.
- Upgrading the ambulance systems to a more powerful Windows 2000-based computer with integrated sleep/power-save management. This resolves outstanding instability issues caused by Windows 95 and protects the system from problems introduced by improper shutdown.

PROGRESS AND SYSTEM RESULTS

Although our system revisions had not been completed at the time of this abstract submission,

we anticipate starting initial field testing in time to present preliminary results at the symposium.

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